EFFECT OF CHEMICAL ADDITIVES ON THE SPREADING QUALITY OF BUTTER. I. THE CONSISTENCY OF BUTTER AS DETERMINED BY MECHANICAL AND CONSUMER PANEL EVALUATION METHODS [1, 2]

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SUMMARY

An instrument, the Consistometer, was perfected for measuring spreadability (by a knife) and hardness (by a wire) of butter. The instrument differentiated between butters with 120 to 500 g. of hardness and 260 to 1,542 g. of spreadability. Such butters ranged between easy to difficult to spread on the basis of a consumer panel evaluation.

Evaluation of 109 commercial butter samples obtained from 14 different states located in different parts of the country revealed a high degree of correlation between the instrument and the consumer panel. The results indicated that the most desirable butter consistency from the consumer's standpoint represents a range on the Consistometer of 400 to 900 g. resistance to the knife, or 140 to 200 g. resistance to the wire, under the conditions of this study. Butters from the same sections and from different sections of the country at the same season varied widely in spreadability and hardness, displaying spreadabilities of 260–1,542 g. and hardness of 120–500 g. About 75% of the samples exhibited a spreadability range of 801 to 1,400 g.

The need for improvement in the consistency of butter is apparent. Statistical analysis of manufacturing data supplied by the companies showed significant correlations between butter spreadability and/or hardness to (a) method of pasteurization, (b) churning temperature, and (c) butter storage temperature.

The rheological characteristics of butter have been studied by a number of subjective and objective methods. The subjective methods involved organoleptic examination and manual ways of spreading the butter on bread or other support (3, 24); whereas, objective methods have dealt with mechanical measurements of compression (4, 13), penetration (14, 18), extrusion (9, 21), cutting (3, 6), spreading (15, 16, 20), viscosity (2, 23), and other variables (1). On the basis of these methods, the consistency of butter has been studied by Hunziker *et al.* (13), Coulter and Hill (4), Dolby (6, 7, 8), DeMan and Wood (5), Wilster (24), Weckel (22), Thomsen (20), and other workers. More recently, Huebner and Thomsen (11) constructed an instrument for measuring both spreadability and hardness of butter, using the basic principles of a similar instrument developed by Mohr and Haesing (16). This instrument was employed by Riel (19) in a study of the spreading character of Canadian butter.

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In the present study of the effect of chemical additives on the hardness and spreadability of butter, it was essential to (a) develop or select a mechanical method for measuring these two variables, (b) determine the limits of desirable improvement in the spreading quality of butter, as indicated by mechanical and consumer panel evaluation methods, and (c) make observations of variation in consistency of butter as related to manufacturing practices.

EXPERIMENTAL PROCEDURE

Collection of samples. A total of 109 butter samples from 100 butter manufacturing plants located in 14 states across the country was obtained by request during the months of December to February, included. The states involved were Oregon, Kansas, Minnesota, Missouri, Ohio, Washington, Iowa, North Dakota, Wisconsin, Oklahoma, Colorado, North Carolina, Louisiana, and Texas. To study possible relationships between manufacturing procedures and the spreadability of butter, a questionnaire on manufacturing techniques accompanied the request for butter samples. About 90% of the butter samples were received in ¼-lb. prints and the remainder was in 1-lb. prints or in bulk form. The butter was stored at 55° F. for 48 hr., after which it was cut into 4½- by 1¼- by 1¼-in. blocks and subjected to testing by the mechanical and by the consumer panel evaluation methods at 55° F.

Selection and construction of the consistency meter. An apparatus was constructed (hereafter referred to as the Consistometer) which was similar in principle to the instrument developed by Huebner and Thomsen (11) but with certain improvements suggested by Huebner (10) (Figure 1). It consists mainly of a pendulum driven by a constant-speed motor. The knife or wire used to spread or cut the butter is mounted at the lowest point of the arc described by the pendulum. The sample to be tested is held in place by a stainless steel frame and it is raised 1/16 in. for the knife, and 1/8 in. for the wire, before each determination. The total resistance to cutting (wire) or spreading (knife) is measured by the sum of the force exerted by fixed weights and by the constant-speed motor. The fixed weights act through a pulley system and the force can be measured directly in grams. The force exerted by the constant-speed motor is registered on a torque-meter which is mounted on the pendulum arm. Improvements to this instrument, involving primarily the pendulum design and the bearing surfaces, increased the sensitivity.

Consumer panel evaluation. To evaluate the spreading character of the butter by manual means, a consumer panel was selected. This consisted of 36 persons of clerical and staff personnel of the University campus. At appropriate times, these panel members, in small groups of three to five at a time, were asked to test the spreading property of the butter. Each panel member did this by spreading a pat of the butter of a standard size (64 pats per pound) on rye bread with a table knife, at a uniform temperature of 55° F. The panelist rated each sample by an 11-point scale, with descriptive terms at

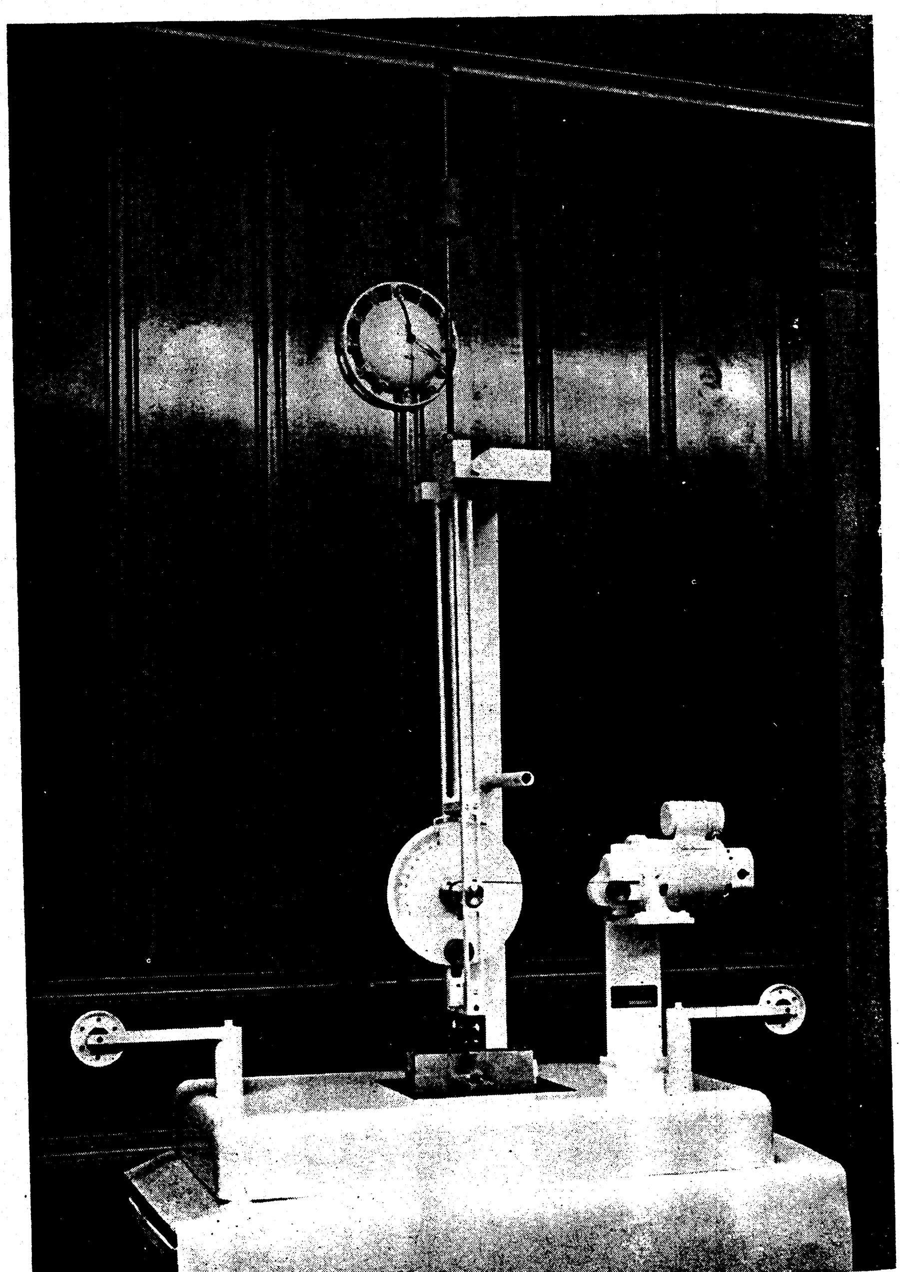

Fig. 1. The perfected Consistometer for measuring hardness and spreadability of butter. (The Accurate Manufacturing Company, Columbus, Ohio.)

2-point intervals, ranging from very easy to spread to very difficult to spread. This score sheet is as follows:

Point	Descriptive Term
11	
10	Very easy to spread
9	
8	Easy to spread
7	
6	Moderately easy to spread
5	
4	Moderately difficult to spread
3	
2	Difficult to spread
1	Very difficult to spread

At each evaluation, a sample of butter of average spreadability was included to assist the panel members in maintaining a proper day-by-day perspective with regard to the range in spreadability.

RESULTS

Reproducibility of the consistometer. To study the reproducibility of the Consistometer, quadruplicate measurements for spreadability and hardness were made on eight samples of butter which varied widely in body characteristics. Results are in Table 1.

The hardness of the eight samples varied from 138 to 363 g. Standard deviation of hardness values ranged from 0 to 32.00 g. and coefficient of variation from 0 to 8.8%. Spreadability values varied from 535 to 1,052 g., standard deviation from 8.15 to 10.10 g., and coefficient of variation from 1 to 2%.

Sample G displayed wide variability in its hardness and spreadability measurements as indicated by the high standard deviation. This may be attributed partly to the relatively great hardness of the sample. By omitting

TABLE 1
Reproducibility of the Consistometer

Sample No.	Hardness (wire)			Spreadability (knife)		
	Resistance to cutting (average)	s[a]	c.v.[b]	Resistance to spreading (average)	s	c.v.
	(g.)	*(g.)*	*(%)*	*(g.)*	*(g.)*	*(%)*
A	141	3.48	2.46	535	10.00	1.80
B	138	0.00	0.00	585	12.80	2.00
C	155	0.00	0.00	685	10.00	1.40
D	188	0.00	0.00	800	8.15	1.00
E	205	0.00	0.00	838	9.80	1.10
F	210	7.07	3.33	903	9.60	1.06
G	363	32.00	8.80	1052	19.10	1.80
H	282	9.40	3.30	[c]		

[a] s = standard deviation.
[b] c.v. = coefficient of variation.
[c] = reading not taken due to erratic swinging of the scale.

results for Sample G, the hardness standard deviation ranges from 0 to 7.07 g. and the spreadability standard deviation from 8.15 to 12.80 g. This indicates smaller variability of the wire measurements than of the knife measurements. The per cent variability of the measurements is similar for both the wire and the knife. Within a large butter consistency range, there seems to be no relationship between hardness or spreadability and variability of the individual measurements. Therefore, the consistometer may be said to give highly reproducible results. However, when extremely hard butter is tested, the variability of both the wire and the knife measurements tends to become greater and for Sample H, erratic swinging of the scale prevented accurate reading of spreadability. In this case, hardness proved more convenient.

Evaluation of commercial butters. The 109 commercial samples of butter were subjected to testing by the Consistometer and to evaluation by the consumer panel. The results are in Table 2. Spreadability values by the Consistometer ranged from 260 to 1,542 g., averaging 1,017 g., and hardness values from 120 to 500 g., averaging 258 g. About 75% of the samples showed a spreadability range from 801 to 1,400 g. On the same samples of butter, consumer ratings ranged from 9.5—easy to spread, to 3.4—difficult to spread, with an average rating of 6.2, which lies between moderately easy to spread and moderately difficult to spread. The possible relationship between the three methods of evaluating butter was examined statistically.

The regression of mechanical spreading, y_k, on the consumer panel ratings, x_p, and the distribution of samples about the regression line are illustrated in Figure 2. The standard error about the regression line is $dy \cdot x = 167.011$, the t value for the coefficient of x_p for 107 d.f is $t = -10.310$, and the correlation coefficient is $r = -0.7057$. The regression indicates that one unit difference in the consumer rating corresponds to 137.644 g. change in spreadability. The null hypothesis for the coefficient of x_p, tested with a "t" test, was rejected

TABLE 2

Spreadability and hardness of butters as determined by the Consistometer and the consumer panel

No. of samples	Consistometer				Consumer panel	
	Spreadability		Hardness		Spreadability	
	Range	Average	Range	Average	Range	Average
	(g.)				(scale points)	
2	260–403	332	120–144	132	9.5–8.8	9.2
2	574–578	576	138–158	149	9.0–8.8	9.2
4	610–690	648	172–197	183	8.1–6.2	7.4
7	724–789	761	176–230	192	7.4–6.0	6.9
13	831–896	869	196–292	222	8.4–4.7	7.0
22	903–991	943	188–273	226	8.4–4.9	6.4
17	1,004–1,090	1,041	200–285	241	7.2–4.5	6.1
16	1,102–1,183	1,137	218–361	268	6.7–4.0	5.8
10	1,216–1,286	1,250	265–430	332	6.4–3.8	5.2
9	1,333–1,400	1,367	292–451	365	6.1–4.5	5.5
5	1,426–1,440	1,435	366–498	448	5.2–4.7	4.9
2	1,514–1,542	1,514	500–500	500	3.4–3.4	3.4
109	260–1,542	1,017	120–500	258	9.5–3.4	6.2

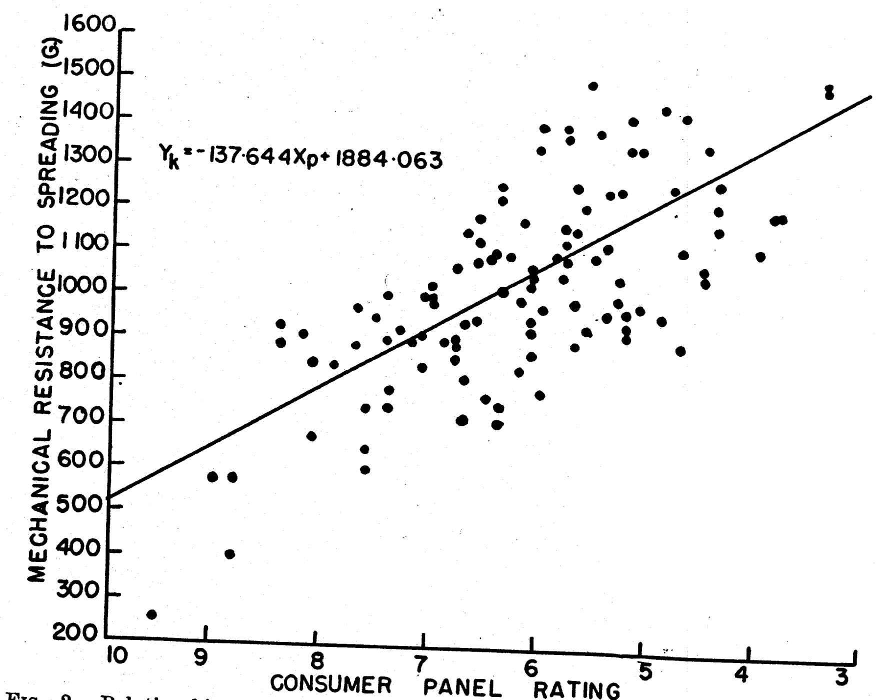

FIG. 2. Relationship between mechanical spreading and consumer panel rating.

at the 1% level of significance. The deviation of samples from the regression line tended to become greater when very soft or very hard samples of butter were tested.

The regression of mechanical hardness y_w on the consumer panel rating, x_p, and the distribution of samples about the regression line are shown in Figure 3. The standard error is $dy \cdot x = 58.585$, the t value $t = -9.509$, and the correlation coefficient $r = -0.6767$. The null hypothesis is rejected at the 1% level of significance. The deviation of samples from the regression line tends to become greater with very hard but not with very soft samples. In general, there is less scattering of the samples than in the case of Figure 2. This may indicate that, in addition to the greater variability of the knife measurement, samples of butter, which on the basis of consumer panel and mechanical hardness methods fall in the same range (Figure 3), can be further differentiated by the mechanical spreading method (Figure 2).

The close relationship between mechanical spreading y_k and mechanical hardness x_w is shown in Figure 4, with $dy \cdot x = 120.213$, $t = 17.454$, $r = 0.8602$, and significance at the 1% level. The deviations from the regression line tended to become greater with both very hard and very soft samples. The lack of uniformity in the hardness and spreadability of commercial butters is clearly demonstrated by the wide scattering of samples along the mechanical as well as the consumer panel scales (Figures 2, 3, and 4).

Based on the consumer panel evaluation results, it appears that the most desirable range for American butter would be from 400 (easy to spread) to

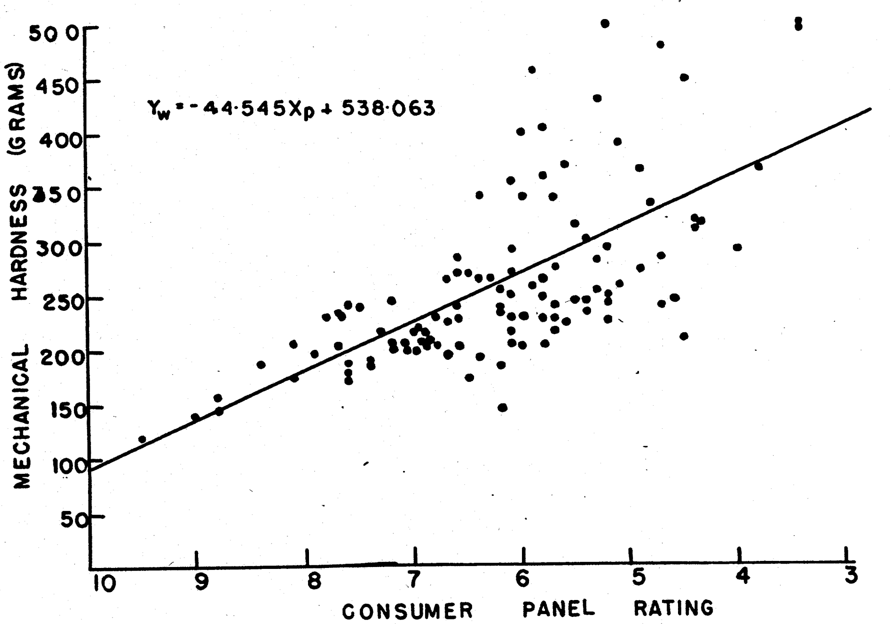

FIG. 3. Relationship between mechanical hardness and consumer panel rating.

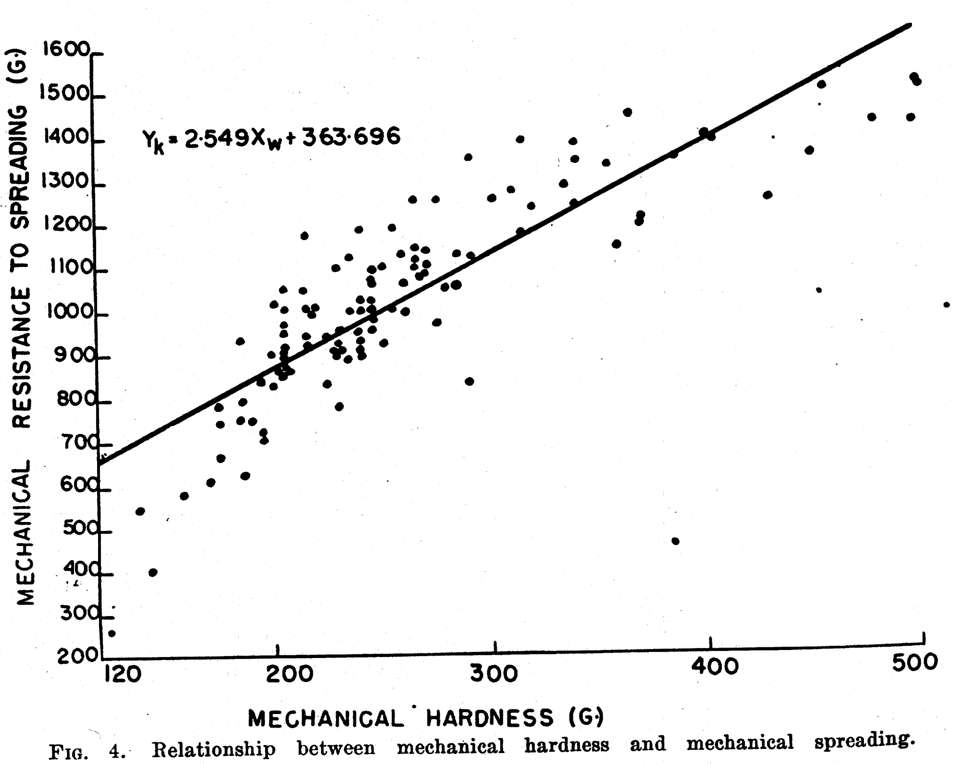

FIG. 4. Relationship between mechanical hardness and mechanical spreading.

900 g. (moderately easy to spread) resistance to the knife or about 140 to 200 g. resistance to the wire under the conditions of this study. This would result in a spreadable and quite uniform butter.

Relationship between manufacturing procedure and the consistency of butter. Forty-six completed questionnaires were returned by the manufacturers who supplied the butter. These contained a variety of information, some of which dealt with: (a) type of cream, (b) method of pasteurization, (c) churning temperature, (d) wash water temperature for the butter, (e) time of storage of the butter before printing, (f) temperature of storage of the butter before printing, (g) printing temperature, and (h) geographic location of the manufacturing plants. Obviously, there were wide variations in the geographic location, feeding practices, manufacturing conditions, temperature, and other factors. Also, it is recognized that the information is solely that supplied by the manufacturer and, consequently, it may be used only as a guide. Nevertheless, it seemed desirable to summarize the questionnaire responses in respect to certain manufacturing practices and to treat these statistically. The results are presented in Table 3.

The statistical analysis reveals that, at the 5% level, the following significant relationships existed:

Pasteurization. The low-temperature long-time method of pasteurization produced the softest and most spreadable butter, followed by the vacuum method. The high temperature–short time method produced the hardest and least spreadable butter. The effect of pasteurization method may have been due to the rate of cooling of the cream rather than to the method of heating (3, 21).

Churning temperature. The lower the churning temperature, the less spreadable was the butter.

Butter storage temperature. The higher the storage temperature before printing, the harder the butter.

No correlation was found between consistency of the butter and the type

TABLE 3
Relationship between manufacturing procedures and the consistency of butter based on the analysis of questionnaire information

Variables	No. of samples	Correlation
Cream		
Farm-separated	14	[a]
Plant-separated	32	[a]
Pasteurization		
Vat	18	[b]
Vacuum	11	[b]
HTST	17	[b]
Churning temperature	46	[b]
Wash water temperature	46	[a]
Storage before printing		
Time	46	[a]
Temperature	46	[b]
Printing temperature	46	[a]
Geographic location	46	[a]

[a] No correlation.
[b] Significant at the 5% level.

of cream, temperature of wash water, length of storage time before printing, printing temperature, and the geographic location. There were wide variations in spreadability and hardness within sections and between sections of the country. Although not included in the statistical analysis, it appeared that continuous churned butter from a given area was harder and less spreadable than conventional butter, but there was some overlapping of values.

DISCUSSION

The Consistometer differentiated clearly between butters which ranged from 120 to 500 g. in hardness and from 260 to 1,542 g. in spreadability. The results reveal that the mechanical method of the Consistometer for measuring hardness and spreadability of butter reflects the consumer reaction to spreadability. However, it is important to note that a higher degree of correlation was obtained between knife and wire than between either of these and the consumer panel. This seems to indicate a weakness in the consumer panel evaluations, due to a probable tendency on the part of the members to avoid extreme ratings. Also, the two mechanical methods are evidently more sensitive than a consumer panel in differentiating between butters, differing only slightly in consistency. Although the Consistometer measures both spreadability (with a knife) and hardness (with a wire), it is more responsive to spreadability changes. In addition, the knife reflects changes over a larger scale of readings than does the wire. However, due to the sensitivity of the knife measurement, variability in spreadability becomes greater as the hardness of the sample increases. When extremely hard samples are tested (above 1,100 g.) there is an erratic swinging of the scale and readings are difficult to obtain. In this case, wire measurements are more convenient and more meaningful than knife measurements. It may be stated that knife and wire register similar as well as different rheological characteristics. For most samples, the combination of knife and wire gives a picture of consistency which seems to be more complete than many of the methods used in the past.

The results of the survey indicate that extreme variation exists in the consistency of commercial butter supplies of the same section as well as of different sections of the country. The need for improvement in spreadability and hardness characteristics is apparent—not only in the actual values but also with respect to uniformity between butters.

Considerable improvement in the spreading character of butter can be accomplished by adjustment of certain processing factors, as indicated by the statistical analysis of the information obtained from the questionnaires. The effect of some of these processing factors has been demonstrated experimentally previously (5, 8, 9). Since the possibility of improving the consistency of butter by adjusting certain processing steps has been known for more than 25 yr. without practical advantage being taken of this knowledge, it would appear that some simpler method of improving butter consistency is needed. One such method would be the use of edible chemical additives to lower the hardness and increase the spreadability. Research in this area is currently under way in this department.

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